

APPARATUS AND METHOD FOR PREVENTING ILLEGAL DISTRIBUTION
OF DIGITAL CONTENTS BY USING A FINGERPRINTING TECHNIQUE

Field of the Invention

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The present invention relates to an apparatus and method for preventing illegal distribution of digital contents by using a fingerprinting technique; and, more particularly, to an apparatus and method for preventing illegitimate distribution of digital contents by using a fingerprinting technique which allows to embed purchaser information to the digital contents, sold through an electronic commercial activity, in the form of a watermark.

15 Background of the invention

In general, recent increase of illegitimate copying and purchase of digital contents through the use of Internet has intensified a demand for a technology capable of protecting intellectual property.

Unlike off-line contents, digital contents on the web can be easily copied and distributed all through the Internet. Thus, various technologies have been developed in order to protect intellectual property in the Internet environment. Among such technologies, there exist an encryption system, an access control system and a copyright

marking system.

The encryption system and the access control system, however, are rarely utilized in recent years since they have a defect that contents can be illegally copied after being
5 legally decoded.

On the other hand, the copyright marking system is gaining popularity since it employs a technique for directly embedding information to a media itself and, thus, can provide legal evidence in case a litigation for a literary
10 piracy occurs, thereby contributing to finding out a copyright holder and an illegitimate distributor of contents.

More specifically, the copyright marking technology can be classified into a watermarking technique, a fingerprinting technique, etc.

15 The watermarking technique is used to prove only the property of contents by embedding information of an owner of the property to contents. Since, however, the same information, i.e., the owner information, is uniformly embedded to digital contents to be sold, all of the
20 watermark embedded digital contents are undistinguishable from each other. For the reason, the watermarking technique is considered as a passive way to protect the property.

The fingerprinting technique, on the other hand, serves to find out a re-distributor of illegally copied
25 contents by embedding information of a legitimate purchaser to the contents. Fingerprinted contents can be

distinguished from each other since it is purchaser information, not property owner information, which is embedded to the digital contents. Therefore, the fingerprinting technique is a more active way of protecting intellectual property than the watermarking technique.

The fingerprinting technique involves three steps of generating, embedding and extracting user information by using an encryption protocol. The user information is embedded to contents by using a user key of a purchaser of the contents and the user key information is preserved in order to use later to trace a distributor of illegal copies of the contents.

Further, there is prepared a registration center (RC) between a seller and a purchaser, which takes charge of generating and embedding a user key, i.e., seller information, thereby allowing to obtain evidence of an illegal purchaser of illegally copied contents, if any.

However, the conventional technologies using the encryption protocol as described above have a defect in that digital contents can be illegally copied after being legally decoded and, further, a new user key can be generated by colluding user keys which have been respectively allotted to individual purchasers. Furthermore, since the fingerprinting technique using the encryption protocol is time-consuming in performing an embedding process due to its use of the encryption protocol, a quality of service (QOS)

may be deteriorated in view of the fact that an e-purchase on the Internet should be processed on a real time basis.

In Eurocrypt97 (1997), there is disclosed a technology for preventing illegitimate distribution of contents by using such a conventional fingerprinting system, entitled
5 "Anonymous Fingerprinting".

The anonymous fingerprinting is a fingerprinting technique using an encryption protocol. Purchaser information is attached to purchased contents. Thus, if the
10 contents are illegally copied and distributed, a legitimate purchaser can be distinguished from illegitimate purchasers by extracting the purchaser information that has been embedded to the contents earlier.

To be more specific, a purchaser of certain contents registers his own purchaser information at a certified
15 registration center. Then, the registered purchaser information is fingerprinted to the contents. A seller generates purchase information including the purchaser information registered at the registration center and, then,
20 embeds to the sold contents the generated purchase information. Then, the seller distributes the purchase information embedded contents after encrypting the contents by using a user's key. If a redistributed content is founded, the seller extracts the embedded information from
25 the redistributed content and sends the extracted information to the registration center to identify the

legitimate purchaser of the contents.

In other words, the purchaser information serves as a single fingerprinting data to identify the purchaser. The purchaser information is embedded to contents when the contents are purchased. This system, however, does not specify where to embed the purchaser information but just suggests a simple transaction method between a seller and a purchaser, which uses an encryption technique.

Further, since multimedia data such as image and audio data is redistributed in a decoded state unlike general software, it is impossible to maintain the purchaser information as fingerprinting information. Therefore, another type of fingerprinting embedding and extraction technique is required in order to use the purchaser information as a fingerprinting data for the multimedia data such as image and audio data.

As described above, the prior-art technologies for protecting intellectual property exhibit drawbacks in that digital contents can be illegally copied after being legally decoded by making use of an encryption technique and, further, a new user key can be generated by colluding user keys already allotted to purchasers.

Summary of the Invention

It is, therefore, an object of the present invention to provide an apparatus and method for preventing
5 illegitimate redistribution of digital contents by employing a non-blind and a blind fingerprinting technique.

In accordance with one aspect of the invention, there is provided an apparatus for preventing illegitimate distribution of digital contents on Internet by employing a
10 fingerprinting technique, including: a first wavelet image obtained by performing a wavelet transformation (WT) to an original image of the digital contents, wherein the first wavelet image has a user information embedding region; a second wavelet image obtained by performing a WT to the user
15 information embedding region of the first wavelet image, wherein the second wavelet image composed of a discrete cosine (DC) region and high-frequency regions; a high-frequency components removed image composed of the DC region and regions obtained by removing high-frequency components
20 in the high-frequency regions of the second wavelet image, i.e., by setting high-frequency components other than the DC as "0", and subjected to an inverse WT (IWT) to be outputted as an IWT image; and a user information embedding unit for embedding user information, which is provided from an
25 operator, to the IWT image, thereby obtaining a user information embedded image with a new user information

embedding region, comparing the user information embedding region of the first wavelet image with the new user information embedding region of the user information embedded image, and embedding the new user information to positions where a difference value between the user information embedding region and the new user information embedding region is small while minimizing a size change of the user information embedding region, to thereby reset the user information embedding region as the new user information.

In accordance with another aspect of the invention, there is provided a method for preventing illegitimate distribution of digital contents on Internet, including the steps of: performing a WT to an original image to obtain a first wavelet image; determining a user information embedding region in the first wavelet image and performing a WT to the user information embedding region, thereby obtaining a second wavelet image; removing high-frequency components from the second wavelet image by setting regions other than the user information embedding region of a discrete cosine (DC) as "0", thereby obtaining a high-frequency components removed image and performing an inverse WT (IWT) to the high-frequency components removed image, thereby obtaining an IWT image; embedding user information provided from an operator to the IWT image to obtain a user information embedded image, comparing a user information

embedding region of the user information embedded image with the user information embedding region and resetting the user information embedding region as a new user information embedding region LL_1 , which is determined by a length and an embedding intensity of a data sequence of the user information in order to minimize deterioration of image quality; and embedding the user information to a position where a difference value between the user information embedding region and the new user information embedding region is small.

In accordance with still another aspect of the invention, there is provided an apparatus digital contents on Internet by employing a fingerprinting technique, including: a first wavelet image obtained by performing a wavelet transformation (WT) to an original image of the digital contents, wherein the first wavelet image has a user information embedding region; a second wavelet image obtained by performing a WT to the user information embedding region of the first wavelet image, wherein the second wavelet image composed of a discrete cosine (DC) region and high-frequency regions; a high-frequency components removed image composed of the DC region and regions obtained by removing high-frequency components in the high-frequency regions of the second wavelet image, i.e., by setting high-frequency components other than the DC as "0", and subjected to an inverse WT (IWT) to be outputted as

an IWT image; and a user information embedding unit for embedding user information, which is provided from an operator, to the IWT image, thereby obtaining a user information embedded image with a new user information embedding region, and embedding the new user information to a position determined by a random sequence generated from a location key in a blind information embedding system which does not use the first wavelet image, to thereby reset the user information embedding region as the new user information.

In accordance with still another aspect of the invention, there is provided a method for preventing illegitimate distribution of digital contents on Internet including the steps of: performing a WT to an original image to obtain a first wavelet image; determining a user information embedding region in the first wavelet image and performing a WT to the user information embedding region, thereby obtaining a second wavelet image; removing high-frequency components from the second wavelet image by setting regions other than the user information embedding region of a discrete cosine (DC) as "0", thereby obtaining a high-frequency components removed image and performing an inverse WT (IWT) to the high-frequency components removed image, thereby obtaining an IWT image; embedding user information and a location key provided from an operator to the IWT image to obtain a user information embedded image,

thereby obtaining a user information embedded image with a new user information embedding region; and embedding the new user information to a position determined by a random sequence generated from a location key in a blind information embedding system which does not use the first wavelet image, to thereby reset the user information embedding region as the new user information.

Brief Description of the Drawings

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The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

15 Fig. 1 shows a non-blind information embedding apparatus in accordance with the present invention;

 Fig. 2 is a flowchart describing operations of the non-blind information embedding apparatus in accordance with the present invention;

20 Fig. 3 illustrates a blind information embedding apparatus in accordance with the present invention; and

 Fig. 4 offers a flowchart explaining operations of the blind information embedding apparatus in accordance with the present invention.

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Detailed Description of the Preferred Embodiments

Referring to Fig. 1, there is provided a non-blind information embedding apparatus in accordance with the present invention. After inputted to the non-blind information embedding apparatus, an original image S1 is subjected to a first-order wavelet transformation (WT) to be outputted as a first wavelet image S2. LL_1 of the first wavelet image S2 is set as a user information-embedding region and is subjected again to a first-order wavelet transformation (WT) to be outputted as a second wavelet image S3. Subsequently, high-frequency components are removed from the second wavelet image S3, i.e., regions other than the region LL_1 of a discrete cosine (DC) are all set to have a value of "0", thereby obtaining a high-frequency components removed image S4 composed of LL_2 serving as a DC region and HL_2 , LH_2 , and HH_2 respectively set to be "0". The high-frequency components removed image S4 is undergone through an inverse WT (IWT), thereby obtaining an IWT image $S4'$ (not shown). Then, user information (UI) S5 provided from an operator (not shown) is embedded to the IWT image $S4'$ to thereby generate a UI embedded image S6. The UI embedded image S6 has a new UI embedding region LL_2' . The new UI embedding region LL_2' of the UI embedded image S6 is compared with LL_1 of the first wavelet image in size and LL_1 is reset as LL_1' which is determined by a length and an

embedding intensity of a data sequence of the UI S5 in order to minimize deterioration of image quality, LL_1' being located in a watermark embedded wavelet image $S2'$ (not shown) corresponding to the first wavelet image $S2$.

5 At this time, the user information $S5$ is embedded to where the size difference between LL_1 and LL_1' is small in order to minimize a size change of LL_1 . To be more specific, values corresponding to $|LL_1 - LL_1'|$ are arranged according to the order of size and data of the user information $S5$ are
10 sequentially embedded to positions of the arranged values in a magnitude order, starting from where a difference value between $LL_1(p)$ and $LL_1'(p)$ is smallest, wherein $LL_1(p)$ represents a p th position of LL_1 and $LL_1'(p)$ refers to a p th position of LL_1' corresponding to the p th position of LL_1 .
15 Thereafter, the watermark embedded wavelet image $S2'$ is undergone through an inverse WT(IWT), thereby obtaining a watermark embedded image $S7$.

Referring to Fig. 2, there are described operations of the non-blind information embedding apparatus in accordance
20 with the present invention.

First, an original image $S1$ is subjected to a first-order WT to be outputted as a first wavelet image $S2$ and user information $S5$ is embedded into a wavelet DC region LL_1 (Step 201). The order number of the wavelet transformation
25 should be carefully selected since it determines the size of the DC region.

The DC region can include the largest amount of the user information S5 when it has a size equal to that of the original image S1. If an n-order WT is performed for an image having a size of M X N, the region LL₁ to which the user information S5 is to be embedded can be determined from the following Eq. 1.

$$size(LL_n) = \frac{M}{2^n} \times \frac{N}{2^n} \quad \text{Eq. 1}$$

At this time, it is preferable that the size of the region LL₁ is determined by considering a length and an embedding intensity of the data sequence of the user information S5, and a degree of image deterioration due to the embedding of the user information S5 data sequence.

After the step 201 is completed, the user information embedding region LL₁ of the first wavelet image S2 is subjected to a first-order wavelet transformation(WT) again to be outputted as a second wavelet image S3 having sub bands of LL₂, LH₂, HL₂ and HH₂ (Step 202).

Thereafter, high-frequency components are removed from the second wavelet image S3 by setting regions other than the region LL₁ of a discrete cosine(DC) as "0", thereby obtaining a high-frequency components removed image S4 composed of LL₂ serving as a DC region and LH₂, HL₂ and HH₂, respectively set to be "0" (Step 203). The high-frequency components removed image S4 is undergone through an IWT,

thereby obtaining an IWT image $S4'$ (Step 204).

Subsequently, user information $S5$ provided from an operator is embedded to the IWT image $S4'$, whereby a user information embedded image $S6$ is obtained. Then, a user information embedding region LL_2' of the user information embedded image $S6$ is compared in size with the user information embedding region LL_1 in order to reset the LL_1 as LL_1' which is determined by a length and an embedding intensity of a data sequence of the user information $S5$ in order to minimize deterioration of image quality (Step 205).

Positions of LL_1' to which data of the user information $S5$ is embedded are determined by comparing components of $LL_1(p)$ and $LL_1'(p)$, wherein $LL_1(p)$ represents a PTH position of LL_1 and $LL_1'(p)$ refers to a pth position of LL_1' (Step 206).

If a component of $LL_1(p)$ is larger than that of $LL_1'(p)$, $LL_1(p)$ is considered as +1 (Step 207) while if a component of $LL_1(p)$ is smaller than that of $LL_1'(p)$, $LL_1(p)$ is regarded as -1 (Step 208).

In other words, since LL_1' is obtained from LL_1 , the size of LL_1 should be properly adjusted to satisfy the binary information. At this time, it is notable that an enough distance K should be secured between LL_i and LL_i' because the value of a DC region, e.g., LL_i , can be changed by an arbitrary attack. The distance K is a variable that serves to determine the embedding intensity of the user information $S5$. The distance K should be set to have a

proper value by considering the fact that if the distance value K is too big or is changed too often, the image quality may be greatly deteriorated.

As such, it is the most efficient way to embed the user information $S5$ to a position where a difference value between $LL_1(p)$ and $LL_1'(p)$ is found to be small since this way enables to minimize a size change of LL_1 . Specifically, values corresponding to $|LL_1 - LL_1'|$ are arranged according to the order of size and data of the user information $S5$ are sequentially embedded to positions of the arranged values in a magnitude order, starting from where a difference value between $LL_1(p)$ and $LL_1'(p)$ is smallest. By performing a series of user information embedding processes described above repeatedly (experiments shows, e.g., ten times is preferable), deterioration of image quality can be greatly reduced (Step 209).

Referring to Fig. 3, there is shown a blind information embedding apparatus in accordance with the present invention. An inputted original image is subjected to a first-order WT to be outputted as a first wavelet image $S2$. LL_1 of the first wavelet image $S2$ is set as a user information-embedding region and is subjected again to a first-order WT, thereby obtaining a second wavelet image $S3$. Subsequently, high-frequency components are removed from the second wavelet image $S3$, i.e., regions other than the region LL_1 of a discrete cosine (DC) are all set to have a value of

"0", thereby obtaining a high-frequency components removed image S_4 composed of LL_2 serving as a DC region and HL_2 , LH_2 and HH_2 respectively set to be "0". The high-frequency components removed image S_4 is subjected to an inverse W_t (IWT), thereby obtaining an IWT image S_4' (not shown). Then, user information (UI) S_5 and a location key S_8 provided from an operator (not shown) are embedded to the IWT image S_4' , thereby generating a UI embedded image S_6 having a new UI embedding region LL_2' . Thereafter, the new UI embedding region LL_2' of the UI embedded image S_6 is compared with LL_1 in size. LL_1 is reset as LL_1' , which is determined by a length and an embedding intensity of a data sequence of the user information in order to minimize deterioration of image quality, LL_1' existing in a watermark embedded wavelet image S_2' (not shown) corresponding to the first wavelet image S_2 .

In the meanwhile, since it is impossible to arrange the values $|LL_1 - LL_1'|$ according to the size order in the blind information embedding apparatus which does not use the first wavelet image S_2 , the embedding positions of the user information S_5 and the location key S_8 are determined arbitrarily to minimize deterioration of the image quality. The wavelet image S_2' in which a watermark is embedded through the user information embedding processes as described above is undergone through an IWT, thereby attaining a watermark embedded image S_7 .

Fig. 4 shows a flowchart describing operations of the

blind information embedding apparatus in accordance with the present invention.

First, an original image S1 is subjected to a first-order WT to be outputted as a first wavelet image S2 and user information S5 is embedded into a wavelet DC region LL₁ (Step 401). The order number of the wavelet transformation should be carefully selected since it determines the size of the DC region.

The DC region can accommodate the largest amount of the user information S5 when it has a size equal to that of the original image S1. If an n-order WT is performed for an image having a size of M X N, the region LL₁ to which the user information S5 is to be embedded can be determined from the Eq. 1 described above.

At this time, it is preferable that the size of the region LL₁ is determined by considering the length and the embedding intensity of the data sequence of the user information S5, and a degree of image deterioration due to the embedding of the user information S5 data sequence.

As described before, the user information embedding region LL₁ of the first wavelet image S2 is subjected to a first-order wavelet transformation (WT) again to be outputted as a second wavelet image S3 having sub bands of LL₂, LH₂, HL₂ and HH₂ (Step 402).

Thereafter, high-frequency components are removed from the second wavelet image S3 by setting regions other than

the region LL_1 of DC as "0" (Step 403) and thus obtained high-frequency components removed image S_4 composed of LL_2 serving as a DC region and LH_2 , HL_2 and HH_2 respectively set to be "0" is subjected to an IWT (Step 404).

5 Afterwards, user information S_5 and a location key provided from an operator are embedded to the IWT image S_4' , whereby a user information embedded image S_6 is obtained. Then, a user information embedding region LL_2' of the user information embedded image S_6 is compared with the user
10 information embedding region LL_1 in size in order to reset the LL_1 as LL_1' which is newly determined by considering a length and an embedding intensity of the user information S_5 , which are found to be the most suitable for minimizing deterioration of image quality (Step 405).

15 Since it is impossible to arrange the values $|LL_1(12) - LL_1'|$ according to the size order in the blind information embedding system which does not use the first wavelet image S_2 , the embedding position of the user information S_5 is determined by a random sequence generated from the location
20 key S_8 in order to minimize deterioration of the image quality (Step 406).

 The random sequence $[locat(K) \in \{0,1\}, 1 \leq k \leq S(LL_n)]$ is set to have a probability defined in Eq. 2. The user information S_5 is embedded to a position corresponding to
25 "1" of the random sequence.

$$P(1) = ui_len / S(LL_n)$$

$$P(0) = 1 - ui_len / S(LL_n)$$

Eg. 2

Herein, ui_len and $S(LL_n)$ respectively represent the size of LL_n and the user information $S5$.

5 Provided in the following description are three experimental results for the blind fingerprinting technique in accordance with the present invention.

Experiment 1

10 16-byte (128-bit) information is embedded to Barbara and Lena's black-and-white picture having a size of 512 X 512 and the embedded information is extracted after a JPEG compression attack has been conducted thereto.

15 Conditions for the experiment 1 are as follows.

- User information $S5$: ETRI WaterMarks! 16 bytes
- Image quality (PSNR) after the embedding of the user information: 44.05 dB (finger_Barb)

20 Table 1 shows the result of extracting the embedded information after the JPEG compression attack is conducted at 46.45 dB (finger_Lena).

Table 1

Image attack Objects	finger_Barb	finger_Lena
JPEG QF 10%	U>□催□□;□	岷 MSeq □□□u□
JPEG QF 20%	dRTGeWMrE(13)iY□	튀 rB□!tm O□+C□
JPEG QF 30%]DRli□terM접k!	□Rl Vat □□r□
JPEG QF 40%	ETRI W!termarks%	□RI GAttermarks!
JPEG QF 50%	ETRI Watermarks!	ETRI Watermarks!
JPEG QF 60%	ETRI Watermarks!	ETRI Watermarks!
JPEG QF 70%	ETRI Watermarks!	ETRI Watermarks!
JPEG QF 80%	ETRI Watermarks!	ETRI Watermarks!
JPEG QF 90%	ETRI Watermarks!	ETRI Watermarks!

5 Experiment 2

Different sets of user information are respectively embedded to the black-and-white picture of 512 X 512 and an averaging attack is conducted thereto. The result is shown
10 in Table 2.

Table 2

Key values for determining an embedding position	Embedded User Information (UI)	Image quality after the embedding of UI (PSNR)	Result Image
3000	joo sanghyun1632	46.14dB	img1
3001	kim jinho8606578	46.00dB	img2
3002	jang howook6694	45.55dB	img3
3003	moon kyungae5340	46.73dB	img4
3004	suh youngho6841	46.45dB	img5

Experiment 3

5 A conspiracy trace is conducted based on correlativity with other images for the averaging attack. The results are provided in Tables 3 and 4.

Table 3

	$\text{avg1}=(\text{img1}+\text{img2})/2$	decision
img1	0.7938	Involved in conspiracy trace
img2	0.7584	Involved in conspiracy trace
img3	0.0417	
img4	-0.0161	
img5	-0.0236	

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Table 4

	$\text{Avg2}=(\text{img1}+\text{img2}+\text{img3}+\text{img4}+\text{img5})/5$	decision
img1	0.4298	Involved in conspiracy trace
img2	0.3665	Involved in conspiracy trace
img3	-0.0068	
img4	-0.0208	
img5	0.4465	Involved in conspiracy trace

As described above, purchaser information is embedded to digital contents sold through electronic commercial activities by employing a non-blind fingerprinting and a blind fingerprinting technique and is extracted depending on allowance or disallowance of the use of an original image. Therefore, illegitimate copying and distribution of the digital contents can be prevented, so that property of the digital contents is effectively protected and safe and legitimate distribution thereof is secured. Further, since the system and method defined in the present invention are compatible with existing encryption systems or control systems using a specific browser and the system is designed to embed information, regardless of whether the information is the user information or any other kind of information related to a use control, to the digital contents in a predetermined input amount, it is possible to identify the owner of the contents and clarify where the responsibility lies even though an encryption of the contents is broken and the contents are illegally distributed. Accordingly, as this technology is known to the public more and more, legitimate distribution of the digital contents can be encouraged. Furthermore, the present technology can be applied, in addition to a stop image, to an audio/video system needing a real-time based embedding and detection. In particular, if the present invention is applied to a video system involving a large data amount, a greater amount

of data can be embedded and, further, a meta data for managing the great amount of data need not be generated.

While the invention has been shown and described with respect to the preferred embodiments, it will be understood
5 by those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the following claims.